The Development of Space Medicine Research in China

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Qualitative methods were employed to analyze the bibliographic metadata of China’s pertinent professional literature to explore the nation’s development of space medicine research. Official information from the China National Knowledge Infrastructure was incorporated into a relational database management system comprised of multiple, self-contained tables of metadata on the scholarly articles of China’s leading space medicine journal: Space Medicine & Medical Engineering. Through a sequential analytical paradigm known as TiROS (Topics and individual Researchers, Organizations, and Sponsors), descriptive statistical treatments were applied to the data of nearly 2,000 records to explore China’s development of space medicine research for transparency and knowledge about the endeavor and the community. Descriptive statistics generated through this approach resulted in data-related objects that enhanced transparency and knowledge relevant to China’s space medicine research programs and initiatives.

I. Introduction

A significant body of published scholarly research has been developed by the People’s Republic of China. Since 1996, the China National Knowledge Infrastructure (CNKI) – a key national project under the auspices of the Chinese Ministry of Science and Technology – has emerged as the most significant information repository for sharing academic knowledge. In particular, the digitized content of the China Academic Journal (CAJ) portion of the CNKI allows for search and retrieval of published articles from over 7,200 journals. This capability is a substantial research tool that provides efficient means to retrieve full-text articles as well as bibliographic metadata. In this regard, the CNKI exists as an important analytical mechanism to help develop transparency into China’s research components as well as increased knowledge about its greater research agenda and community.

II. Research Methodology

Answers to many questions about Beijing’s research into space medicine can be obtained by evaluating China’s scholarly literature on the subject. A review of individual professional journal articles resulting from space medicine research and experimentation in China allows for singular insights into investigative projects, researchers, and organizations. In addition, articles are occasionally published in China with summary descriptions or statistical characterizations of the nation’s space medicine research from the larger perspective of specific programs or research discipline citations and bibliometrics. However, these approaches are insufficiently comprehensive to reflect Beijing’s larger space medicine research arrangement or to yield the requisite data to describe the undertaking in great detail.

Within this setting, a significant research problem exists on how to describe China’s development of space medicine research in a fashion that enhances transparency into its individual components and leads to increased knowledge about its greater agenda and community. Within this context, qualitative methods were employed to analyze the bibliographic metadata of China’s pertinent professional literature to explore the nation’s research into space medicine. Official information from the CNKI repository was incorporated into a relational database management system (RDBMS) comprised of multiple, self-contained tables of metadata on the scholarly articles of China’s leading space medicine journal: *Space Medicine & Medical Engineering* (SMME).

*Figure 1* reflects the availability of SMME metadata from its initial publication in 1988 through 2007, as reflected in the CNKI holdings. It is assumed that prior to the publication of SMME, Beijing conducted and shared the results of its space medicine research through non-public means. Presumably, the majority of this research occurred under the aegis of the Institute of Space Medico-Engineering (ISME), which was established in 1968 through the merger of several existing aviation medicine and space medicine research institutions in Beijing. Although the various CNKI data points of SMME published research – such as keywords, researcher names, and so forth – are not comprehensive, sufficient details exist to conduct a significant review of the development of China’s space medicine research over the 20-year period.

![Figure 1: CNKI Availability of Space Medicine & Medical Engineering Metadata](image)

Through a sequential analytical paradigm known as TiROS (Topics and individual Researchers, Organizations, and Sponsors), it is possible to apply descriptive statistical treatments to the CNKI-derived data of nearly 2,000 SMME records to explore the China’s space medicine research for transparency into the core elements of the investigative endeavor and...
knowledge about the larger community. The TiROS model (see Figure 2) leverages available CAJ SMME metadata (see Figure 3) from the perspective of the key variables required to describe the development of space medicine research in China in terms of the agenda (topics) and community (researchers, organizations, and sponsors).

**Figure 2: TiROS Analytical Model**

**Figure 3: Sample SMME Research Article**
III. Key Findings

In accordance with the design of the TiROS analytical model and the availability of the CAJ SMME metadata, the research findings contributed to increased transparency and knowledge about China’s space medicine research agenda and community. The key findings in terms of transparency and knowledge are outlined below.

Transparency. The following transparency was gleaned through the TiROS model.

Type of Research:

* SMME is the leading journal for distributing the results of space medicine research and experimentation to the community of interest in China. The journal is published in Chinese on a bi-monthly basis and contains about 100 scholarly articles annually. Most of the articles result from original research, but a smaller number of reports stem from literature reviews or special research topics. In general, the research reflects significant levels of academic rigor among Chinese researchers. The original research adheres closely to the scientific method in terms of a standardized reporting sequence of stated research objective, methodology, results, and conclusions.

* About 90% of China’s space medicine research as reflected in SMME is dedicated to general issues of health and medicine. In recent years, the interests of the space medicine research community have matured from broad aerospace applications toward an emerging discipline of operational space medicine. In this regard, research into applied basic medicine is beginning to exceed efforts directed to the specialized topics of space medicine and medical engineering. Along with this linear trend, the observation of new research initiatives in topics such as aerospace psychology suggests that Beijing is laying the medical foundation for manned space flight missions of longer duration.

* Nearly 3,800 distinct keywords have been noted in SMME reports since 1988, with each article having 4-8 keyword entries. Although terms such as simulated weightlessness, acceleration, and hypoxia are common, the analysis of keywords was deemed to be insignificant and unreliable because their assignment is the prerogative of the principal author, is open-ended, and lacks a rigorous editorial review process.

Researchers:

* Most of China’s space medicine research is conducted by investigative teams as opposed to sole individuals. Teams of 3-6 personnel are common, accounting for over 80% of all SMME articles since 1999.

* It is difficult to categorize the Institute of Space Medicine Research (ISME) (China’s most prolific space medicine research organization) as an overt civilian or military institution. To retain analytical objectivity, it is useful to treat ISME as belonging to its own category. In this
scheme, about 60% of the primary authors of SMME reports since 2002 were civilian researchers; the remaining 40% was nearly evenly divided among ISME and military personnel.

* A disparity of gender exists among the primary authors of SMME reports since 2002. Women frequently serve as primary authors, accounting for over one-third of all SMME articles since 2002. However, the gender proportion is misleading because civilian institutions account for nearly 60% of all SMME scholarly articles since 2002, and women led the research for over 40% of these reports. Substantial gender imbalances were noted in the research leadership at ISME and the military institutions, where the relative proportion of women as primary authors was found to be just 34% and 20%, respectively.

* About one-fourth of the primary authors of SMME published research have only a master’s degree education, while the primary authors with a doctorate accounted for another 23%. A notable disparity exists in the academic credentials of the primary authors, depending on the workplace. Civilian organizations have the highest numbers of SMME primary authors with more than a master’s degree, to include a predominance of published researchers with doctorates. Conversely, the military organizations had fewer advanced academicians, particularly among doctoral students. However, more than one-third of the primary authors from military organizations had a doctorate. Nearly one-half of the primary authors attributed to ISME had only a master’s degree.

* Civilian organizations have the greatest proportion of professors who led research initiatives that resulted in SMME articles. ISME’s published lead authors are largely designated as researchers, although it also has a relatively high number of engineers. The military has a relatively flat distribution of personnel across the range of professional disciplines, as well as the largest number of physicians who lead space medicine research. These findings suggest that civilian institutions are comprised of academicians in tenured assignments as part of ongoing programs of education. Conversely, ISME personnel are likely employed in a dedicated space medicine research center. The involvement of Chinese military organizations in space medicine research is less characterized by a dichotomy between academic and research interests.

* Over 370 distinct research specialties have been noted in SMME reports since 2002. Although interests such as medical image processing, biomedical engineering, and biomechanics are common, an analysis of research interests was deemed to be insignificant because their assignment is the prerogative of the principal author, is open-ended, and lacks a rigorous editorial review process.

Organizations:

* Although China’s published space medicine research rarely resulted from inter-organizational collaboration in the 1980’s and 1990’s, a distinct increase in such collaboration has occurred since 2000. In 2007, the number of SMME articles resulting from collaborative work between organizations exceeded the number from single organizations for the first time.
The trend suggests that the relative proportion of inter-organizational collaboration will continue to increase.

* In China, a group of 20 organizations account for about 90% of the primary organizations that produced SMME research since 1991. Five institutions are notably prolific, accounting for about 70% of all SMME reports: ISME, the Fourth Military Medical University (FMMU, located in Xi’an), Sichuan University (located in Chengdu), the Air Force Institute of Aviation Medicine/Air Force General Hospital, and Tsinghua University. ISME alone accounted for nearly 44% of the SMME published space medicine research, well ahead of figures attributed to FMMU. A total of 119 organizations led research efforts resulting in SMME articles since 1991.

* Beijing has for many years been the leading area for China’s space medicine research. However, its elite status began to wane from 2000 as organizations of the provinces of Sichuan and Zhejiang expanded their leadership role in producing space medicine research. Based on the number of SMME reports, China’s space research organizations can be divided into three distinct tiers. The top level consists of organizations in Beijing, Shaanxi, Sichuan, Shanghai, and Zhejiang. A middle level consists of organizations in Tianjin, Anhui, and Hubei. A third level is comprised of organizations of 16 regions that only occasionally contribute to published space medicine research.

* Civilian organizations such as Tsinghua University, the University of Science and Technology (USTC) (located in Hefei, Anhui Province), Zhejiang University (located in Hangzhou), and Sichuan University have multiple academic departments that contribute to SMME published research as lead organizations, suggesting that a broader scope of space research interests exists at these institutions. In addition, several civilian organizations house State Key Laboratories that conduct space medicine research directly under the auspices of the State Planning Commission. Tsinghua University and Zhejiang University are the only civilian institutions that operate both a State Key Laboratory as well as multiple academic departments that led space medicine research efforts that resulted in SMME scholarly articles. This phenomenon suggests that a multidisciplinary intra-organizational space medicine research effort exists at these organizations, either a purposeful individual initiative or a portion of larger, broad-based research programs at these two universities.

* As reflected in Figure 4, the Beijing municipality is the leading center of China’s published space medicine research. It hosts a broad array of organizations, including ISME, civilian, and military institutions, many of which have multiple departments or State Key Laboratories. The municipalities of Xi’an and Shanghai host a substantial number of civilian and military organizations, among which FMMU (in Xi’an) is the top military facility. In recent years, the urban centers of Chengdu (Sichuan) and Hangzhou (Zhejiang) have emerged as important regions of space medicine research, although most institutions in these areas are overtly civilian organizations that also oversee multiple departments that engage in space medicine experimentation.
Figure 4: Key Facilities Conducting Space Medicine Research in China

Sponsors:

* The external sponsorship of space medicine research in China is a comparatively recent phenomenon that gained prominence in SMME articles only in the past eight years. Today, the list of sponsors includes civilian, military, national, international, provincial, university, and municipal sources. The (China) National Science Foundation (NSF) and the China High Technology Research and Development Program (Project 863) are the two most longstanding supporters of Beijing’s space medicine research, accounting for nearly one-half of all funded investigations that led to SMME articles. Sponsorship of published space medicine research by the China National Manned Space Program (Project 921) and the Ministry of Education (MOE) increased significantly since 1999.

* Twenty-two sponsors of Beijing’s space medicine research collectively account for nearly 90% of all SMME primary sponsor citations. The NSF, Project 921, and Project 863 have served as the three leading sponsors of space medicine research since the 1990’s, collectively accounting for over two-thirds of all funded research that led to SMME articles.

* Administratively, the sponsors of Beijing's space medicine research can be classified into five broad categories: national, provincial, university, municipal, and international. National-level sponsors—such as the NSF, Project 921, and Project 863—for years have been predominant in underwriting such research, accounting for over 90% of the funded projects that led to SMME articles since 1988.
Civilian sponsorship programs accounted for the majority of underwritten space medicine research published in SMME since 1988, representing over two-thirds of all such citations during the period. However, the number of SMME articles that stemmed from military sponsorship programs increased sharply from 1999-2003 before leveling off since 2004. Although still a new and limited phenomenon, several SMME articles have been published from research that was jointly underwritten by both civilian and military sources since 2001.

Although as many as five different funding sources have sponsored an individual SMME research article, the utilization of a single sponsor is most common, accounting for nearly 80% of the total citations. However, since 2000 multiple sponsors have commonly collaborated in the underwriting of space medicine experimentation (see Figure 5), particularly in terms of 2-3 different sponsors that collaborated in the publication of SMME reports.

Knowledge. The following knowledge was gleaned through the TiROS model.

In terms of organizations and sponsors, the top 17 sponsors of research resulting in SMME articles account for 86% of all sponsor citations. NSF was the lead sponsor of both civilian and military research initiatives that led to a similar role for research conducted at ISME. Collectively, these two programs comprised over 55% of all sponsor citations that resulted in SMME articles. Project 863 has supported research at civilian organizations and ISME, but has only occasionally been used to underwrite research at military facilities. The remaining sponsors generally targeted the research population that is inherent in their characterization, to include a substantial number of space medicine research initiatives sponsored by the Medical Research Foundation of the People’s Liberation Army that led to SMME reports from overt military organizations. ISME relies heavily on Project 921 and Project 863 funding, which collectively underwrote over 83% of the its reports published in SMME. Conversely, FMMU relied on the NSF and the Medical Research Foundation of the People’s Liberation Army to fund nearly two-
thirds of its research that resulted in SMME articles. Researchers at Sichuan University draw principally from NSF sponsorship.

* In terms of its sponsors and topics, the preponderance of sponsored research as manifested in SMME articles stemming from Beijing’s space medicine research components and community is directed to the discipline of space medicine and medical engineering. This broad research interest is vested in the three major sponsors (NSF, Project 921, and Project 983) as well as in two military sponsors (the Medical Research Foundation of the People’s Liberation Army and the PLA General Armaments Department). More than two-thirds of the sponsorship of research among the leading topics of interest that led to SMME reports was underwritten by two national funding sources: NSF and Project 921.

* In terms of topics and researchers, many researchers at ISME, civilian, and military organizations led multiple research efforts since 2002 that resulted in SMME articles. As a result, a nascent coalescence of subject matter expertise is being established among these individuals and within these institutions. It is likely that iterative and advanced research is now possible among specific topical agendas and through the development of distinct communities of interest.

* In terms of researchers and organizations, as many as 324 distinct primary authors led space medicine research efforts that resulted in more than one SMME scholarly article through 2007. Since 2002, 262 SMME articles resulted from primary researchers who led the production of more than one report through 2007. ISME is the leading organization for such investigations, reflecting the significant expertise that exists within the institution. Similarly, Sichuan University and FMMU were the core civilian and military space medicine research organizations, respectively, in terms of distinct numbers of researchers within the community.

**IV. Conclusions**

Through the detailed review of the relevant Chinese literature, the existence of a large number of scholarly journal articles describing the results of Beijing’s space medicine research and experimentation was identified. Specifically, it was found that SMME in particular was dedicated to sharing the results of Beijing’s space medicine research with the interested community of scientists, researchers, technicians, and science and technology managers. Moreover, the standardized format and structure of the SMME articles over its twenty-year period of existence was found to allow for a purposeful exploration of the CAJ relevant metadata for increased transparency and knowledge.

The conclusions of the project resulted from an initial investigation of the complex topic of the development of space medicine research in China. In this regard, the findings successfully enhanced transparency and knowledge. However, much work remains to be accomplished to build upon the baseline of transparency and knowledge for a true understanding of the missions and functions of space medicine research in China. Although the TiROS model yielded substantial gains in transparency and knowledge regarding Beijing’s development of space medicine research, several gaps remain. The most notable shortfalls stem from the inherent
limitations of a data aggregational approach, namely (1) a lack of data specificity, standardization, and coverage across the 20-year period, and (2) the inability of observed data to account for and explain the underlying factors of the data points. Accordingly, the areas for further investigation include enhanced methodologies and the development of more detailed analytical models to build upon the preliminary findings of this AIAA project.

V. Recommendations

A greater appreciation of the development of space medicine research in China would require a detailed analysis of the composition and interworkings of the relevant research variables, particularly beyond the identification of the primary topics, researchers, organizations, and sponsors. Follow-on research initiatives might involve substantial computing power in the sense that the trends of Beijing’s published space medicine research are (1) toward broader and more complex topics; (2) larger and more diverse research teams; (3) inter-organizational and inter-regional collaboration; and (4) the leveraging of more and varied sources of sponsorship. Accordingly, an ideal exploitation of the complex metadata would require sophisticated software to incorporate research involving statistical techniques, such as data clustering, multiple link analysis, relational data mining, timeline analysis, and data visualization. These steps are worth taking if transparency, knowledge, and understanding will be among the future objectives of an exploration of China’s space medicine research components, agenda, and community.

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